# Influence of Covering Materials and Shading on the Greenhouse Cooling in Iraq

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## Abstract

Cooling greenhouses is essential to provide a suitable environment for plant growth in arid regions. However, using conventional cooling methods are facing many challenges. Filtering out near infra-red radiation (NIR) at the greenhouse cover can significantly reduce the heating load and can solve the overheating problem of the greenhouse air temperature. Four cases of shadings were examined for their ability to improve the indoor condition of a greenhouse cooled by indirect direct evaporative cooler: (shade 1) a single layer of polyethylene film, (shade 2) a double layer of polyethylene film, (shade 3) a double layer of polyethylene film with a green mesh layer (shade 4) a double layer of polyethylene film with a Utrecht Corrugated Cardboard with 3cm holes distributed for incident sun light. An experimental study is conducted to determine the performance parameters of indirect direct evaporative cooling of greenhouse in Baghdad (33.3 $^{o}$N, 44.4$^{o}$E) for the four types of shadings. It was found that the percentage reduction in light intensities for shade 1, shade 2 and shade 3 are 15%, 25% and 40% respectively. It percentage reduction solar intensity due to shades is increases at the beginning and ending of sunny period, while it was minimum at noon. The percentage reduction in temperature due to indirect direct evaporative cooling for the shade1, shade 2 and shade 3 and shade 4 are 32.4, 36.3, 42.4, and 47 respectively. The percentage increasing in relative humidity due to indirect direct evaporative cooling for the shade1, shade 2 and shade 3 and shade 4 are 562.5, 729, 871, and 788 respectively. The percentage increasing in temperature due heating load of greenhouse for the shade1, shade 2 and shade 3 and shade 4 are 41.4, 33.2, 20.5, and 11 respectively. The percentage decrease in relative humidity due heating load of greenhouse for the shade1, shade 2 and shade 3 and shade 4 are 43.4, 31, 11.8, and 7 respectively.

## 1. Introduction:

The main technical problem of greenhouses is to maintain air temperatures and relative humidity that are favorable for plant growth in the greenhouse. This can be achieved by heating greenhouse air in winter and cooling

In summer. In cool regions, the technology for heating greenhouses is well established and straightforward. However, in hot and sunny regions, cooling the greenhouse air is a more difficult challenge than heating due to the fact that advances in the greenhouse cooling technology are still limited compared with heating systems. In addition, cooling systems are more expensive to install and operate than heating systems. Several efforts have been made worldwide to adopt greenhouses to hot and sunny climate conditions [1]. Even though, an extensive survey was provided for the greenhouse cooling technologies worldwide [2, 3]; however, their survey focused on greenhouses located in tropical and subtropical regions and those located in regions characterized by mild climate such as the south part of Europe. However, in regions characterized by an arid climate with brackish water resources, a discussion for adapting an adequate cooling technique that can be used for greenhouses is still missing.

Climate in arid regions is characterized by hot and long summer seasons (the ambient temperature exceeding 45◦C at around noon in summer), high solar radiation flux (the daily solar radiation integral reaches to 30 MJ/m$^2$), dusty and dry weather (relative humidity of the ambient air drop below 10% at around noon), and water resources being scarce and brackish (salty).

In Iraq, the temperature reaching 48 to 50$^{o}$C in some hot summer days [4]. This condition was not able to assist the using of greenhouses in summer, while they are built for using in winter, i.e. these systems were ignored in summer. This gives losses, especially when these systems are located in a rich Land suitable for agriculture. In the other hand, when developing the cooling system for greenhouses to be more easer, with low power consumed, easy to maintenance, and with using geothermal water for cooling as well as for irrigation, it is able to invest desert for cropping.

There are more research dealing with using covers and shade of greenhouses[1]. L. Mascarini, et. al. [5] used plastic shading meshes, colored (blue, green) and non colored (grey, white and black). The greenhouses were placed; the conclusion is that with the blue mesh, a higher commercial quality plant is obtained. Zhang and Wang [6] studied the shade of cloths,the illuminance and the irradiance increase with the exterior illuminance and the irradiance.Between the inside and the outside,the illuminance and the irradiance have certain linear relationship separately. T. Gunhan , , V. Demir, A.K. Yagcioglu[7] evaluated the suitability of pumice stones, volcanic tuff and greenhouse shading net as alternative pad materials to the widely used and commercial one called CELdek. They tested four levels of air velocity (0·6, 1·0, 1·3 and 1·6 m/s) four levels of water flow rate (1·0, 1·25, 1·5 and 1·75 L/min) and three levels of pad thickness (50, 100 and 150 mm). The tests were made at 30±1 °C and 40±1% relative humidity air conditions. The temperature of water flow was kept constant at 25±2 °C during the tests. According to the results of this study, they conclude that the volcanic tuff pads are good alternatives to the CELdek pads at 0·6 m/s air velocity. Kittas et. al.[8] measured the solar photon flux distribution under a twins pan glasshouse and under the same glasshouse with blanked roof, external shading net and internal aluminized shade screen. Measurements were also carried out under a twin span polyethylene greenhouse, a multi span greenhouse with fiberglass and a polyethylene tunnel for each greenhouse configuration.

In this research work, indirect direct evaporating cooler was designed to cool greenhouse built in Baghdad with four cases of shadings were (1) a single layer of polyethylene film, (2) a double layer of polyethylene film, (3) a double layer of polyethylene film with a green mesh layer (4) a double layer of polyethylene film with a Utrecht Corrugated Cardboard with 3cm holes distributed for incident sun light. The water source for indirect direct evaporative cooler was from geothermal well to increase the performance of cooling as well as for irrigation.

## 2. Materials and Methods

The apparatuses used for this work are greenhouse, cooler, and measuring instruments.

### 2.1 Greenhouse

An experimental gable-even-span greenhouse model has designed, constructed, and installed at the Baghdad (latitude 33.3ºN, longitude 44.4ºE, and altitude 32 m above the sea level). The geometric characteristics of the gable-even-span model are as follows: eaves height 2 m, gable height 0.7 m, span angle 26.6º in the south side and 35º in the north side, width 2.0 m, length 2.5 m, floor surface area 5.0 $m^2$, and volume 11.2 $m^3$.

The greenhouse structural frame is formed from wooden plates (5×5 cm). The experimental greenhouse is covered with double polyethylene sheet (PE, UV) 300μm thick with gape of 5 cm. It was orientated in East- West direction, where the southern longitudinal direction faced into the sun's rays. The cooler is located in the west side and the door in the south side. Two ventilation openings were located in the center of the roof with total area of 0.25$m^2$.

Four types of shading were used which were:

(Shade 1) a single layer of polyethylene film

(Shade 2) a double layer of polyethylene film

(Shade 3) a double layer of polyethylene film with a green mesh layer

(Shade 4) a double layer of polyethylene film with a Utrecht Corrugated Cardboard with 3cm holes distributed for incident sun light

Figure (1) shows the schematic diagram and pictures for the present greenhouse

### 2.2 Indirect-direct evaporating Cooling unit

Based on the greenhouse dimensions and structure the required flow rate can be estimated by [2]:

$$Q = A_g \frac{0.003\tau R_{s,o-max}}{\Delta T}$$

Where:

$Q$: is air flow rate required ($m^3/s$)

$A_g$: is the greenhouse ground surface area, in $m^2$ ($A_g$=2 $m^2$)

τ: is the greenhouse transmission coefficient to solar radiation in present work is equal to 0.8 [3]

$R_{s,o-max}$ :is the maximum outside solar radiation W /$m^2$ which is measured about 1000 W/$m^2$,

$\Delta T$ : is the temperature difference between greenhouse and outside air, in ºC (it is about 18ºC).

Then Q = 0.26 $m^3/s$ which is the capacity of fan used in the present work

Based on the conversion of sensible heat into latent heat by means of evaporation of water supplied directly into the cross-fluted cellulose cooling pads, the collected water in the sump was allows equal to the dew point temperature of the entering air. Thus, the cold water supplied through the cooling coil during the experimental period as revealed in Fig. (1). The cooling coil consists of heat exchanger and water supplied lines installed 20 cm before the first stage direct evaporative cooling. Three stages of 3cm cellulose pads were used with 15 cm space between each two. The heat exchanger is made of 39 finned cupper tubes (6mm diameter, 0.4 mm thickness, aluminum corrugated plate fines) arranged in vertical three rows. The gross dimensions of cooling coil are: 33 cm high, 36.5 cm wide and 6.5 cm thick. The section of the system duct is (38 * 44) cm which is galvanized steel plate with steel structure the dimensions of pads is (33 *40) cm each. For this dimension the air velocity through the pad is about 2m/s. and this give overall evaporating pad efficiency of about 65% [14]. A steel tank with capacity of 25 L is used for evaporating cooling water with two submersible water pump of for coil and pads with capacities of 2 L/s n 3L/s respectively. The makeup water is from geothermal well of 8m deep. Figure (2) shows the schematic diagram and figure (3) shows the picture of cooler.

## 2.3 Measuring Instruments

The measuring instruments consists of:

1- air temperature and relative humety measuring device with 16 humidity and temperature probs (AM2301) connected to urduino uno card. the probs is putted in a cork cup to to avoid sun array. The distribution of probes is as follows.

HT00 and HT01: outdoor in the in a cork cup and befor coil respectively.

HT02 after coil

HT03 after fisrt pad

HT04 after second pad

HT05 after third pad

HT07 after fan pad

HT07. HT08 &HT09 inside the greenhouse, at line 0.5 m from south wall and 1m elevation.

HT10. HT11 &HT12 inside the greenhouse, at line 0.5 m from north wall and 1m elevation.

HT13. HT14 &HT15 at vertical line located in the center of green house at defferent elevations (0.3, 1, & 2)m

The probs were calibrated with certificated new HTL prob (LabJack).

The probs and there distribution was shown in figure (4).

2- water temperature measurement used for inlet and outlet of the coil, well water temerature and greenhouse soil tempreatute, these probes were connected to asecone urduino uno card . the probs were calibrated by comparing the reading with a mercury thermometer.

3- Soller intesity was measured using daystar meter.

4- Airflow rate using AM4214SD hotwire anemometer and AM4210 vanprobe anemometer.

5- Water flow rate using UCC rotometer calibrated at 20$^o$C.

6- Pressure drop in air flow thrrough the processes using PM-9102 digital manometer which was calibrated using U-tube manometer.

Figure (5) shows the mesuerment Instruments used in this work

## 3. Result and Descutions

The direct and through shades solar intensity for the days of work were measured and plotted in figure (6). It was shown that the soller intensity has a maximum values of about 1000W/m$^2$ through the time 12:00 to 1:00 pm. It was shown that the shade 4 give higher reduction of light intensity because of obsorving the light by green mesh as well as the double layer of polyethelen, while shade 1 give lower reduction of light intensity for single layer of polyethelen. In between, the double layer of polyethelen. Figure (7) give the percentege reduction in the light intensity due to the present shades used. It was shown that the percentege reduction has amximum values at the beginning and ending of sunny peroid, while it was minimum at noon for all types of covers. This is because of light incident angle. When this angle is around right angle in the noon, the light will be penetrate minimum distance in the shade materiale. And as the light incident angle will increases ( or decreses) the light will penetrate more distanse in the shade materiale and then the percentege reduction will be increseases.

The cooling system which is designed for one air-water heat exchanger as indirect evaporative cooler and three pads as direct evaporative cooler was run for four shading types. The temperature and humidity were measured through the run. Figure (8) shows the temperature and humidity for the outdoor, through the cooling processes and for the indoor of green house for the case of shade 3. It was shown the temperature increased reaching maximum of 48$^o$C (T1)at the noon while the percentage of humidity ratio reaching minimum value of about 7% (f1). the temperature was decreased through the cooling processes for the indirect-direct cooler stages reaching 22$^o$C in the noon. At the same time the percentage relative humidity reaching 65%. Inside the greenhouse the condition at the noon is 27$^o$C and 60% RH due to heating load in the greenhouse. Figure (9) shows the representation of on the psychometric diagram for the maximum outdoor temperature. It was shown that the moisture content for the direct evaporative part (1 to 2) was kept constant at 0.005kg/kg dry air, while the enthalpy is kept approximately constant for evaporative part for cooling system (58kJ/kg dry air) (2 to 5). The process from cooling air inlet to the greenhouse (5) to inside greenhouse (in) is sensible heating as shown in figure (9) (line 5-in) because of high rate of moisture content through this process.

Figure (10) shows the comparison of greenhouse temperatures and the values of percentage relative humidity for greenhouse with different covers. It was shown that the shade 4 give lower inside temperature (24$^o$C$^)$ and higher relative humidity (70%) due to lower incident solar light. Figure (11) shows the comparison of temperature and relative humidity differences between greenhouse and outdoor for different covers it was shown that shade 1 give lower temperature and relative humidity diferances because it is allowed largest amount of solar light to incident to the greenhouse. This give higher heat transfer to the greenhouse and then the temperature of greenhouse was increased. Figure (12) Comparison of percentage differences of temperature and relative humidity greenhouse with outdoor and outlet of the cooler for different covers. It was shown that the percentage differences in relative humidity between outdoor and greenhouse has order of hundreds because of evaporating cooling which increase the percentage relative humidity from 7% to 70%. The percentage differences of temperature shows that as the layers of cover increases the percentage of differences of temperature between outdoor and greenhouse increases and percentage of differences between cooling air and greenhouse decrease due to high because of decreasing the radiation heat transfer as the cover layers increases. The percentage differences in relative humidity between outdoor and greenhouse is increases as the cover layer increases and in the cartoon cover was decreased due to condensation.

Table 1 summarizes the results obtained by the types of shade used for approximately same outdoor conditions and the resultants of indoor of greenhouse condition with the differences and the percentage of variation.

**Table 1:** Temperature and relative humidity for outdoor and inside greenhouse for the types of covers used

| Cover Type | $T_o$ [°C] | $RH_o$ % | $T_{in}$ [°C] | $RH_{in}$ % | RHin-Rho | (To-Ti) [°C] | (To-Ti)/To *100% | (RHin-RHo)/Rho *100% | Tc | (Ti-Tc) [°C] | (Ti-Tc)/Tc *100% | Rhc | RHc-RHin | (RHc-RHin)/RHc *100% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shade 1 | 46 | 8 | 31.1 | 53 | 45 | 14.9 | 32.4 | 562.5 | 22 | 9.1 | 41.4 | 76 | 23 | 43.4 |
| Shade 2 | 46 | 7 | 29.3 | 58 | 51 | 15.7 | 36.3 | 729 | 22 | 7.3 | 33.2 | 76 | 18 | 31.0 |
| Shade 3 | 46 | 7 | 26.5 | 68 | 61 | 19.5 | 42.4 | 871 | 22 | 4.5 | 20.5 | 76 | 8 | 11.8 |
| Shade 4 | 46 | 8 | 24.4 | 71 | 63 | 21.6 | 47 | 788 | 22 | 2.4 | 11 | 76 | 5 | 7.0 |

It was shown that the maximum decreasing in temperature is for shade 4 ($24.4^{O}C$) because of maximum decreasing in the incident solar intensity, while for a single layer of polyethylene the maximum temperature was recorded ($31.1^{o}C$).

## 4- Conclusions

In this work, four types of greenhouse covers were used which were:

(Shade 1) a single layer of polyethylene film

(Shade 2) a double layer of polyethylene film

(Shade 3) a double layer of polyethylene film with a green mesh layer

(Shade 4) a double layer of polyethylene film with a Utrecht Corrugated Cardboard with 3cm holes distributed for incident sun light

The main conclusions are:

1- The percentage reduction in light intensities for shade 1, shade 2 and shade 3 are 15%, 25% and 40% respectively.

2-. It percentege reduction soler intensity due to shades is increases at the beginning and ending of sunny peroid, while it was minimum at noon.

3- The percentage reduction in temperature due to indirect direct evaporative cooling for the shade1, shade 2 and shade 3 and shade 4 are 32.4, 36.3, 42.4, and 47 respectively.

4- The percentage increasing in relative humidity due to indirect direct evaporative cooling for the shade1, shade 2 and shade 3 and shade 4 are 562.5, 729, 871, and 788 respectively.

5- The percentage increasing in temperature due heating load of greenhouse for the shade1, shade 2 and shade 3 and shade 4 are 41.4, 33.2, 20.5, and 11 respectively.

6- The percentage decrease in relative humidity due heating load of greenhouse for the shade1, shade 2 and shade 3 and shade 4 are 43.4, 31, 11.8, and 7 respectively.

## References

[1] A.M. Abdel-Ghany, I. M. Al-Helal, S. M. Alzahrani, A. A. Alsadon, I. M. Ali, and R. M. Elleithy, “Covering Materials Incorporating Radiation-Preventing Techniques to Meet Greenhouse Cooling Challenges in Arid Regions: A Review, The Scientific World Journal, ID 906360, 11 pages doi:10.1100/2012/906360,Volume 2012.

[2] V. P. Sethi and S. K. Sharma, “Survey of cooling technologies for worldwide agricultural greenhouse applications,” *Solar Energy*, vol. 81, no. 12, pp. 1447–1459, 2007.

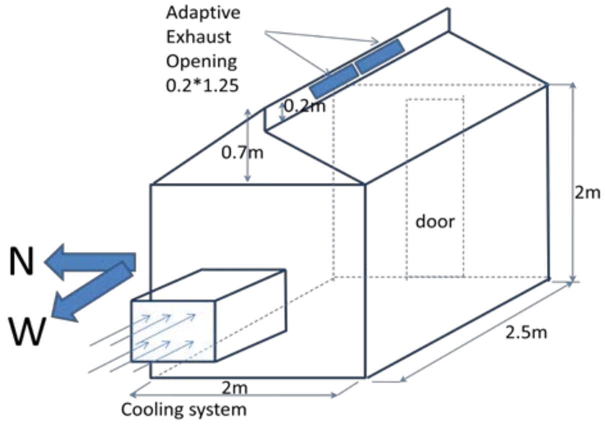
[3] K. S. Kumar, K. N. Tiwari, and M. K. Jha, “Design and technology for greenhouse cooling in tropical and subtropical regions: a review,” *Energy and Buildings*, vol. 41, no. 12, pp. 1269–1275, 2009.

[4] Issam Mohammed Ali, Hind Dhia’a Ridha, “Indirect-Direct Evaporative Cooling of Greenhouse by using Geothermal Energy” Iraqi Society of Engineers, The First Conference for Ensuring Renewable Energy for Better Environment, December 9-10,2015

[5] L. Mascarini, A. Mascarini, M. Goldberg, A. Landini, S. Orden, F. Vilella,” EFFECT OF GREENHOUSE SHADING MATERIALS ON THE FOLIAR AREA AND FLOWERING OF TWO CYCLAMEN PERSICUM HYBRIDS”, V International Symposium on Protected Cultivation in Mild Winter Climates: Current Trends for Sustainable Technologies 2001

[6] Zhang Yanling, Wang Xiaochan, “Comparative Study on Illumination and Temperature Characteristic of Different Style

Shade Cloths of Greenhouse" Energy Conservation Technology, S625, 2008.
[7] T. Gunhan, V. Demir, A.K. Yagcioglu," Evaluation of the Suitability of Some Local Materials as Cooling Pads", Biosystems Engineering, Volume 96, Issue 3, March 2007, Pages 369–377
[8] C. Kittas, A. Baille, P. Giaglaras," Influence of Covering Material and Shading on the Spectral Distribution of Light in Greenhouses", Journal of Agricultural Engineering Research, Volume 73, Issue 4, August 1999, Pages 341–351.




Dimensions of greenhouse

Shade 1

Shade 2

Shade 3

Shade 4

**Figure 1:** schematic and pictures for the present greenhouse

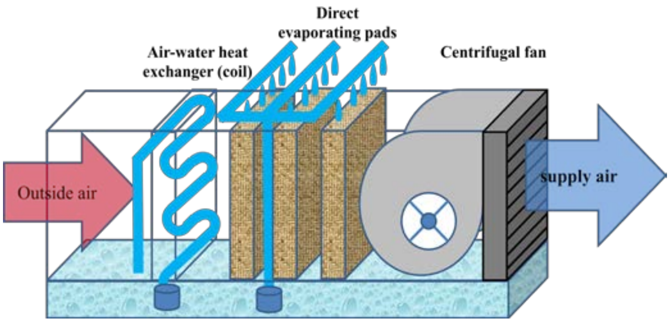



**Figure 2:** shows the schematic diagram of cooler

**Figure3:** shows the cooler

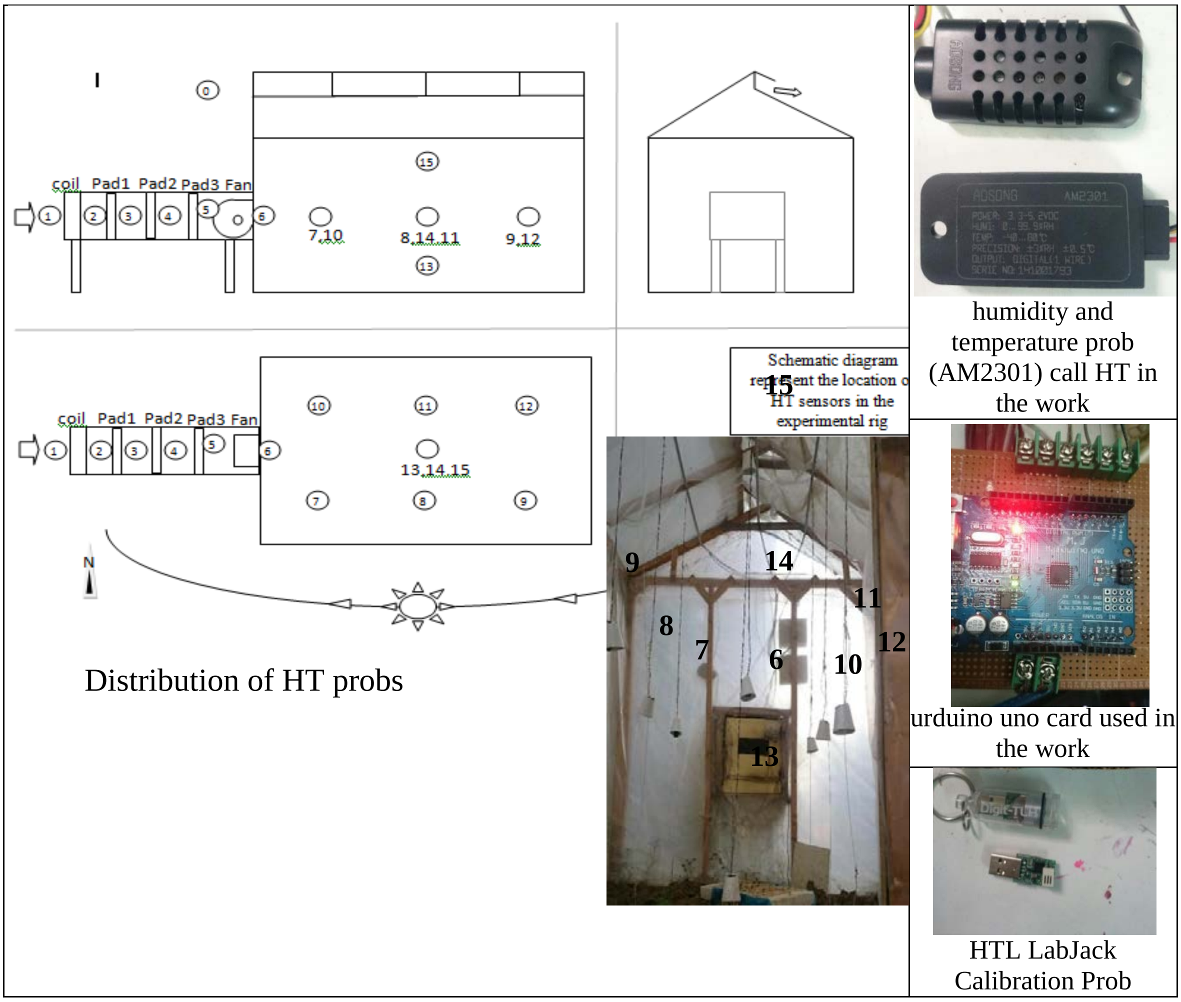



**Figure 4:** The humidity temperature (HT) probs and there distribution.

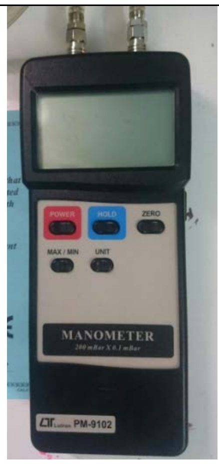
|  |  |  |  |  |
|---|---|---|---|---|
| daystar solar meter | AM4214SD hotwire anemometer | AM4210 vanprobe anemometer | PM-9102 digital manometer | UCC rotometer |

**Figure 5:** the Instrumentes used in the work

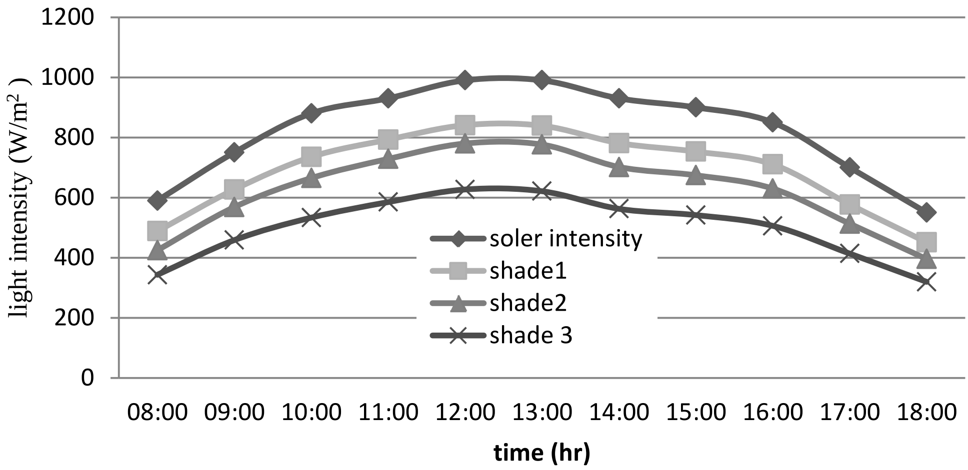



**Figure 6:** Measuring solar Intensity for differnet greenhouse cover

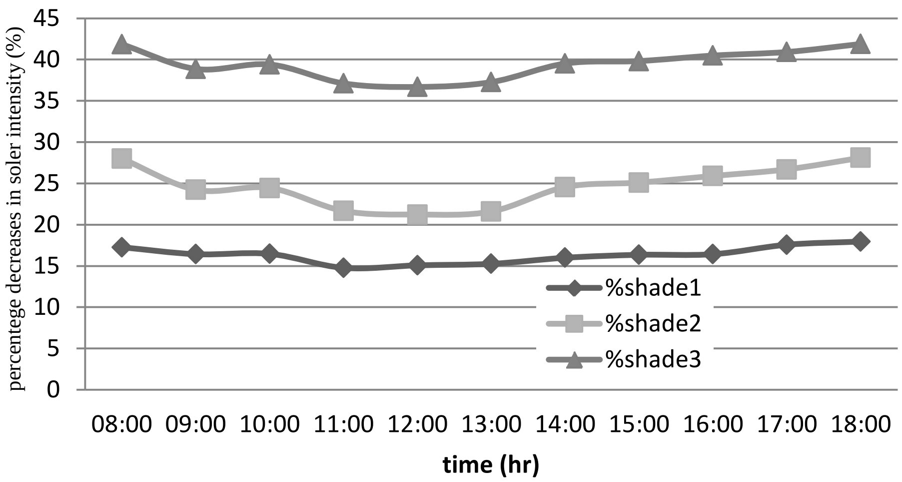



**Figure 7:** Percentege reduction of solar Intensity for differnet greenhouse cover

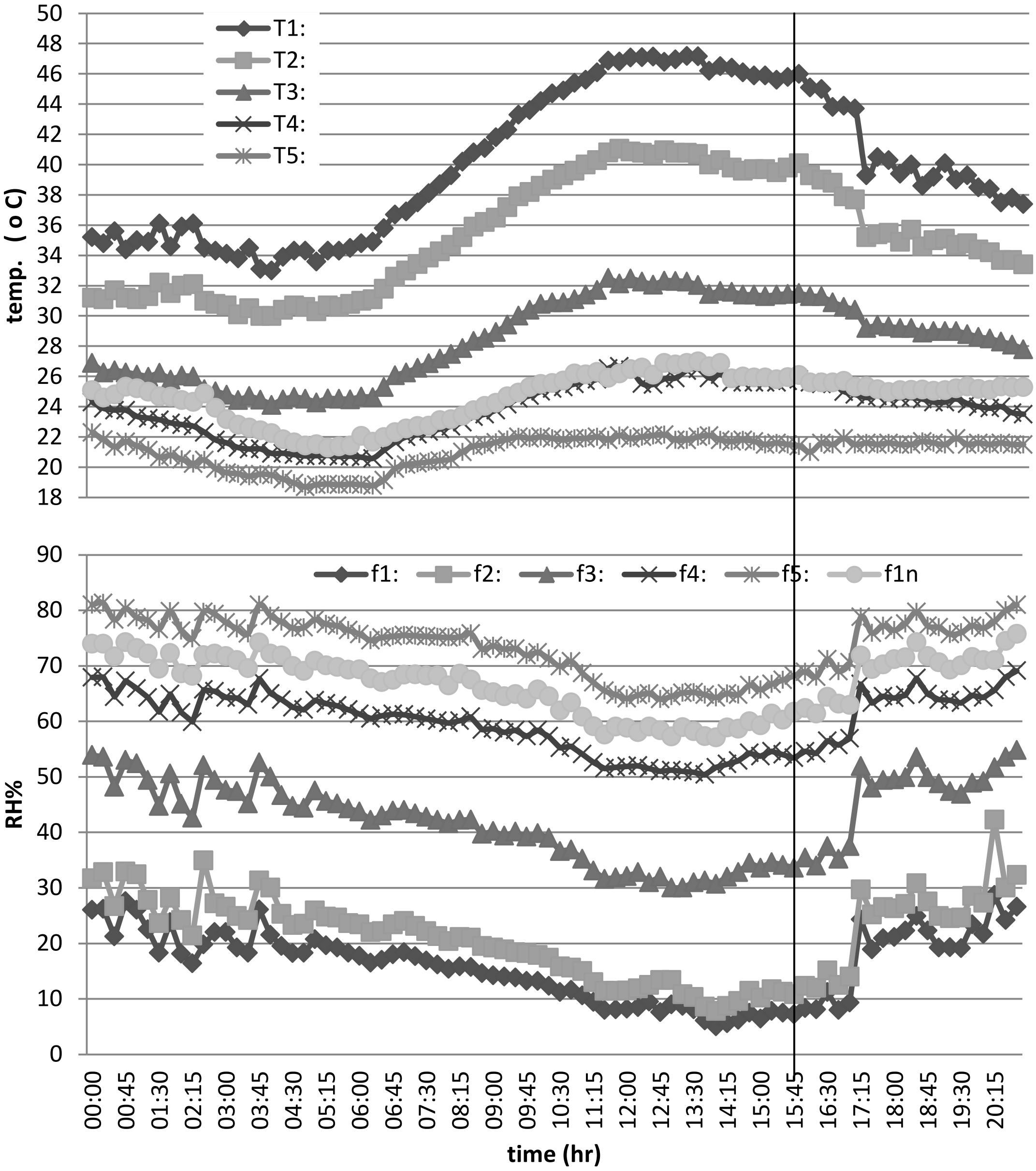



**Figure 8:** The temperatures and values of percentage relative humidity plotted versus time for different stages of indirect-direct evaporative cooling and inside greenhouse.

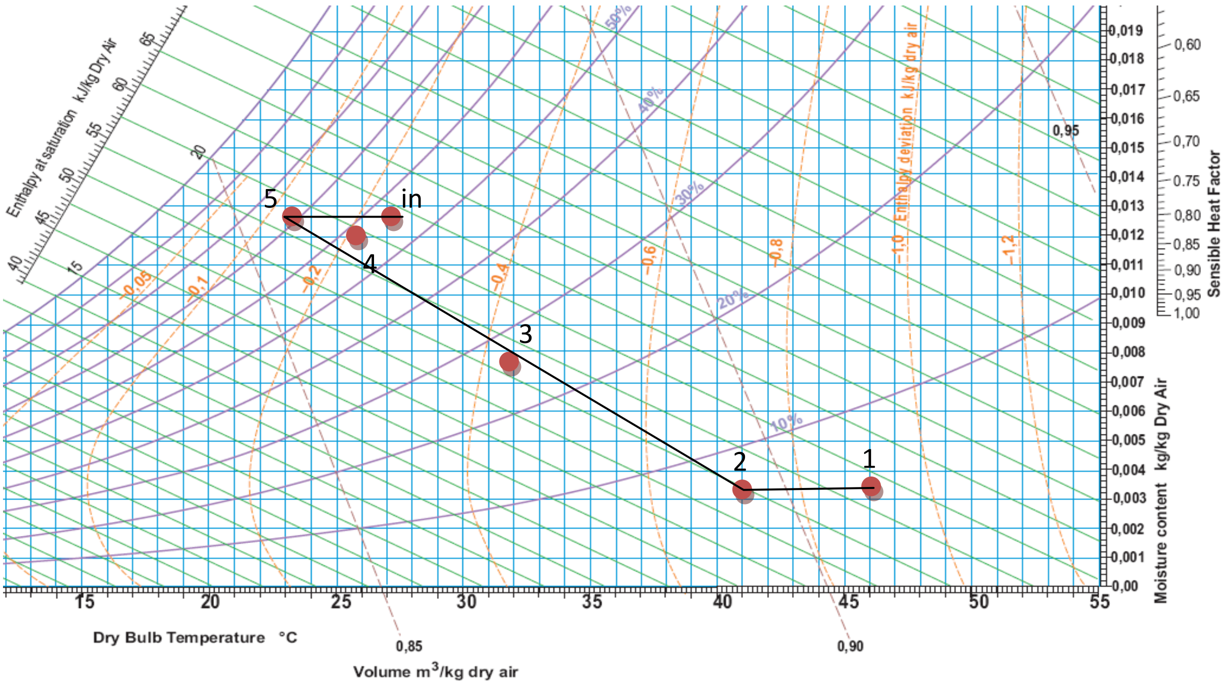



**Figure 9:** Psychometric representation of indirect direct evaporative cooling of greenhouse with shade 3.

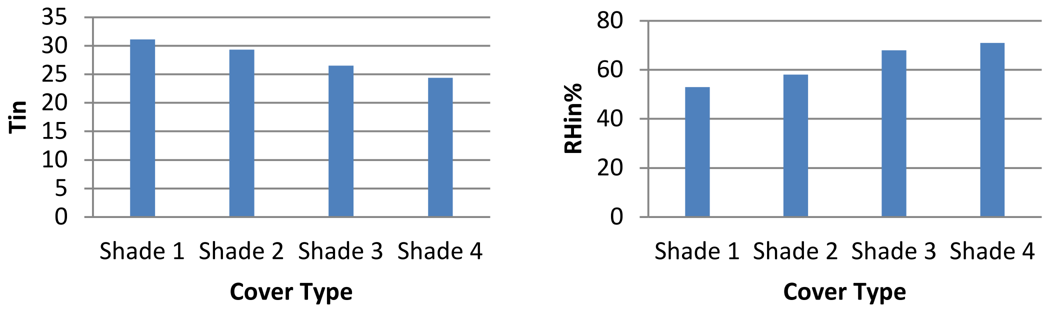



**Figure 10:** Comparison of greenhouse temperatures and the values of percentage relative humidity for green house with different covers

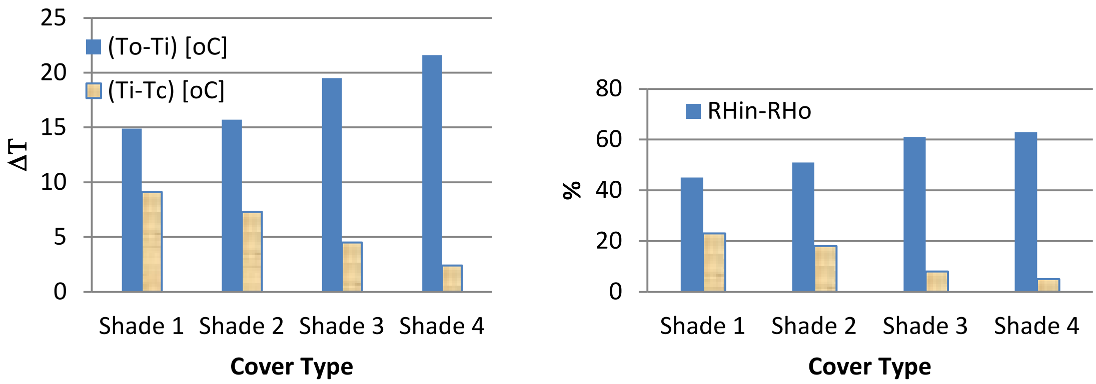



Figure (11) Comparison of temperature and relative humidity differences between greenhouse and outdoor for different covers

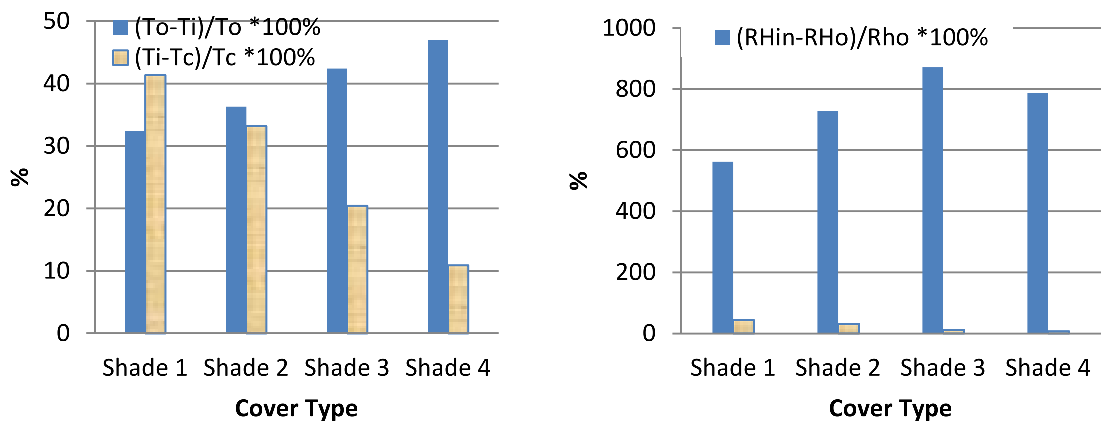



**Figure 12:** Comparison of percentage differences of temperature and relative humidity greenhouse with outdoor and outlet of the cooler for different covers

# دراسة تاثير مواد التغطية و التضليل على اداء تبريد البيوت المحمية في العراق

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**الخلاصة:**

يعد تبريد البيوت المحمية من الامور الضرورية لتوفير مناخ مناسب لنمو النباتات في المناطق الجافة. يواجه استخدام اساليب التبريد التقليدية الكثير من التحديات المادية و الفنية اضاقة الى شدة الاشعاع الشمسي ووجود الاشعة تحت الحمراء المؤذية للنبات و التي تزداد خطورتها في البيوت المحمية مع وجود ظاهرة الاحتباس الحراري. في هذا البحث تم اختبار اربعة انواع من اغطية و تضليل البيوت الزجاجية المبردة بالتبريد التبخيري (غير المباشر-المباشر) وهي (الظل1) طبقة واحدة من البولي إثيلين، (الظل 2) طبقة مزدوجة من البولي إثيلين، (الظل 3) طبقة مزدوجة من البولي ايثلين مع طبقة الظل الأخضر (الظل 4) طبقة مزدوجة من البولي إثيلين مع طبيقة من الكرتون المقوى المثقب بثقوب موزعة بقطر 3 سم لتسمح بمرور جزأ من اشعة الشمس. تبين أن نسبة الخفض في شدة الضوء للظل 1و الظل 2 والظل 3 هي 15٪و 25٪ و 40٪ على التوالي. كذلك ان نسبة تخفيض الاشعاع الشمسي نتيجة الظلال تكون عالية في بداية النهار ونهايته ، في حين سجل اقل نسبة انخفاض ظهرا. وان نسبة الخفض في درجات الحرارة بسبب التبريد التبخيري (غير مباشر-المباشر) عن الظل 1و الظل 2 والظل 3 و الظل 4 هي 32.4، 36.3، 42.4 و 47 على التوالي. و نسبة الزيادة في الرطوبة النسبية بسبب التبريد التبخيري (غير المباشر-المباشر) هي 562.5، 729، 871، 788 على التوالي و نسبة الزيادة في درجة الحرارة نتيجةالاحمال الحرارية المسلطة على البيت الزجاجي هي 41.4، 33.2، 20.5 و 11 على التوالي. واخيرا وجد ان نسبة الانخفاض في الرطوبة نتيجةالاحمال الحرارية المسلطة على البيت الزجاجي هي 43.4، 31، 11.8 و 7 على التوالي.